US009730216B2

(12) **United States Patent**
Wang et al.

(10) **Patent No.: US 9,730,216 B2**
(45) **Date of Patent: Aug. 8, 2017**

(54) **METHOD AND SYSTEM FOR ENABLING MULTIPLE TRANSMISSION IN WIRELESS SYSTEMS**

(75) Inventors: **Jianfeng Wang**, Ossining, NY (US); **Monisha Ghosh**, Chappaqua, NY (US)

(73) Assignee: **KONINKLIJKE PHILIPS N.V.**, Einghoven (NL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 323 days.

(21) Appl. No.: **13/808,350**

(22) PCT Filed: **Jul. 5, 2011**

(86) PCT No.: **PCT/IB2011/052964**

§ 371 (c)(1),
(2), (4) Date: **Jan. 4, 2013**

(87) PCT Pub. No.: **WO2012/004737**

PCT Pub. Date: **Jan. 12, 2012**

(65) **Prior Publication Data**

US 2013/0114553 A1 May 9, 2013

Related U.S. Application Data

(60) Provisional application No. 61/362,030, filed on Jul. 7, 2010.

(51) **Int. Cl.**
H04W 72/04 (2009.01)
H04W 28/26 (2009.01)
H04L 5/00 (2006.01)

(52) **U.S. Cl.**
CPC ***H04W 72/0446*** (2013.01); ***H04W 28/26*** (2013.01); *H04L 5/0005* (2013.01)

(58) **Field of Classification Search**
CPC . H04W 72/0446; H04W 80/00; H04W 72/04; H04W 4/00; H04Q 7/00; H04B 1/40; H04B 1/38; G06F 13/372
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2006/0198353 A1 9/2006 Wason
2008/0137606 A1* 6/2008 Zuniga et al. 370/330
(Continued)

FOREIGN PATENT DOCUMENTS

WO WO2006111826 A1 10/2006
WO WO2006120648 A2 11/2006
(Continued)

OTHER PUBLICATIONS

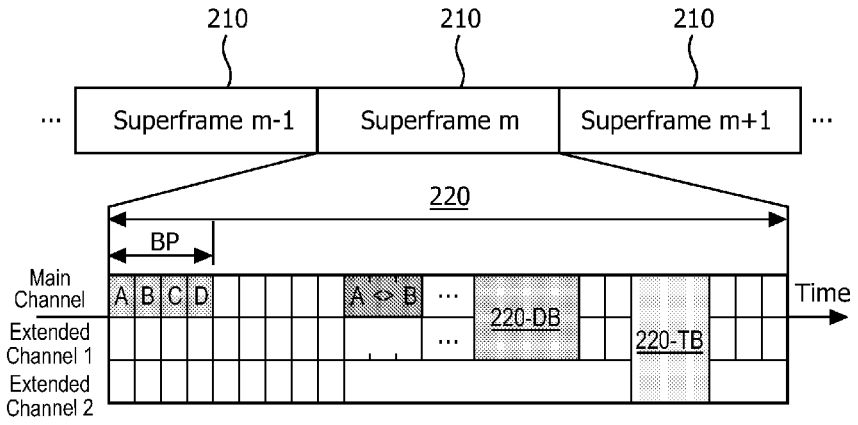
"Standard ECMA-368—High Rate Ultra Wideband PHY and MAC Standard", ECMA 3rd Edition—Dec. 2008.

Primary Examiner — Charles C Jiang
Assistant Examiner — Wali Butt
(74) *Attorney, Agent, or Firm* — Larry Liberchuk

(57) **ABSTRACT**

A method (**900**) for medium access reservation in a multi-band wireless network comprises determining available slots (**220**) for reservation in a superframe (**210**) for reservation across multiple channels (S**910**); generating channel reservation protocol (CRP) availability information element (IE) (**310**) to indicate the available slots on a main channel; generating one or more Extended-Channel CRP availability IEs (**500**) to indicate the available slots on one or more respective extended channels (S**920**); exchanging the CRP availability IE and the Extended-Channel CRP availability IEs between a receiving device and a transmitting device (S**930**); and generating a Multiband CRP IE (**600**) to reserve slots that are available on the receiving device and the transmitting device (S**940**).

19 Claims, 6 Drawing Sheets



(58) **Field of Classification Search**
USPC 725/131; 370/328–336; 455/73; 710/117
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0232311	A1*	9/2008	Reumerman et al.	370/329
2008/0259895	A1	10/2008	Habetha	
2009/0036063	A1*	2/2009	Zuniga et al.	455/73
2009/0322941	A1	12/2009	Hatanaka	
2010/0177718	A1*	7/2010	Harle	H04W 72/00 370/329
2011/0205962	A1*	8/2011	Das et al.	370/328

FOREIGN PATENT DOCUMENTS

WO	WO2008070067	A2	6/2008
WO	WO2010024784	A1	3/2010
WO	WO2010073158	A1	7/2010

* cited by examiner

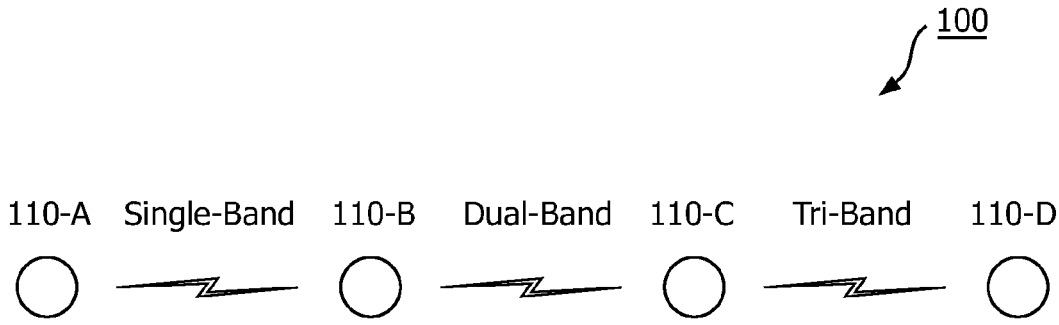

100
110-A
Single-Band
110-B
Dual-Band
110-C
Tri-Band
110-D

FIG. 1

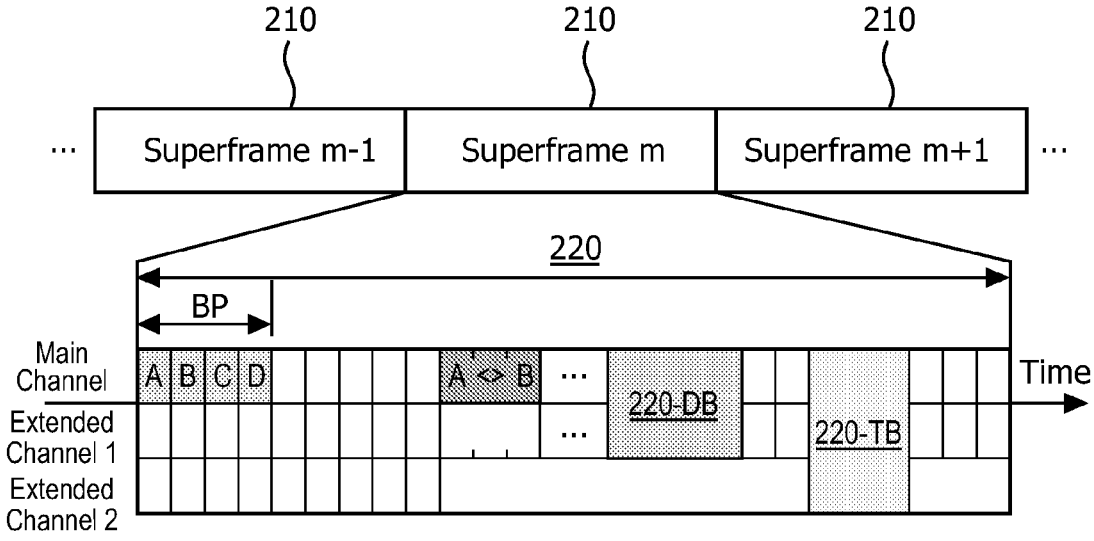

210
210
210
Superframe m-1
Superframe m
Superframe m+1
220
BP
Main Channel
Extended Channel 1
Extended Channel 2
A
B
C
D
A <> B
220-DB
220-TB
Time

FIG. 2

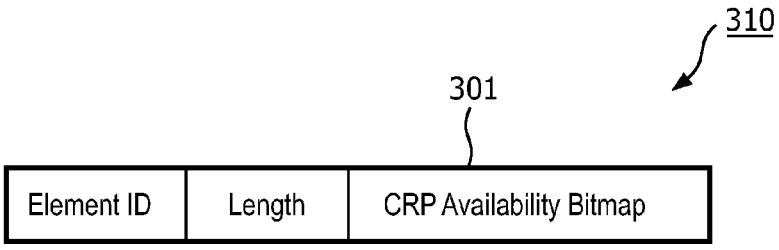


FIG. 3A

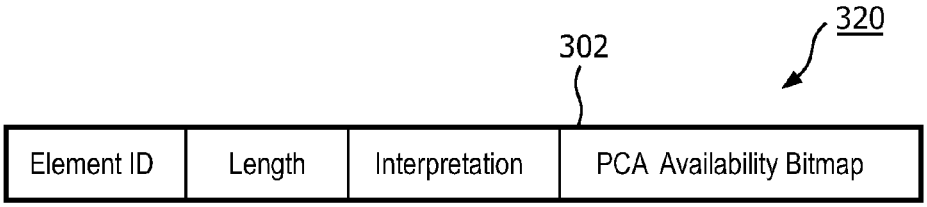


FIG. 3B

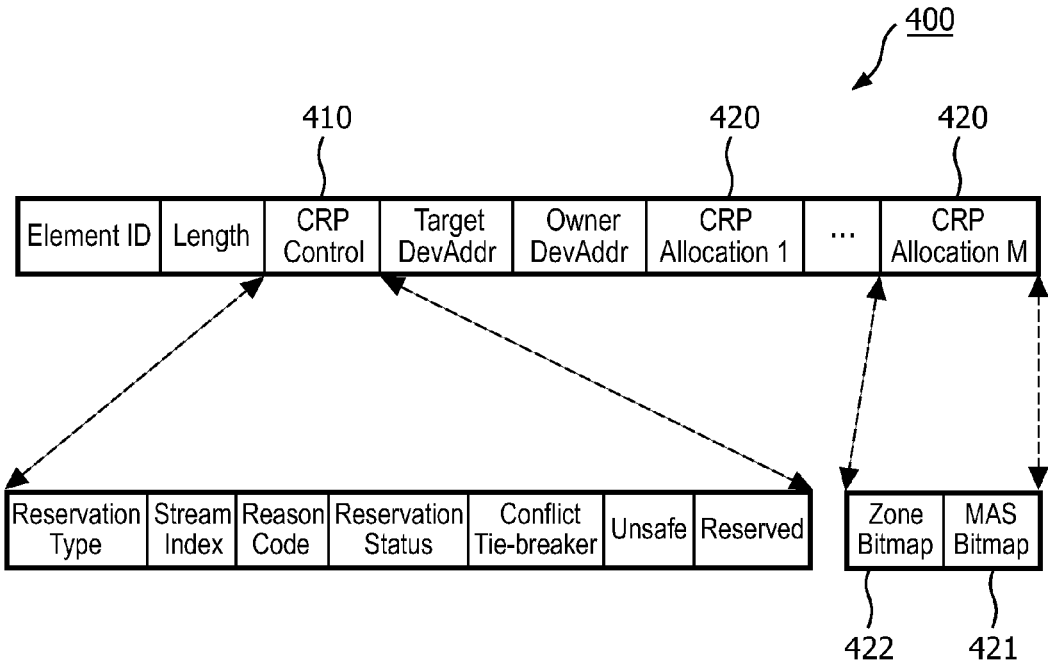


FIG. 4

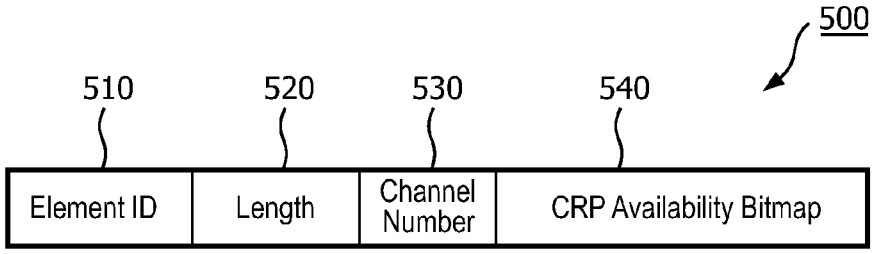


FIG. 5

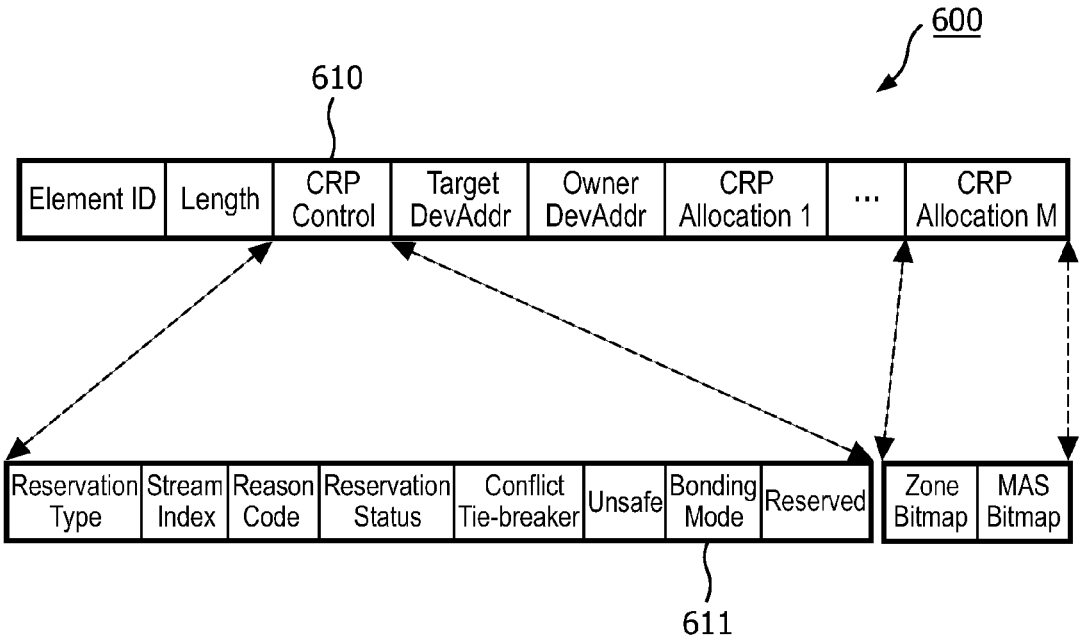


FIG. 6

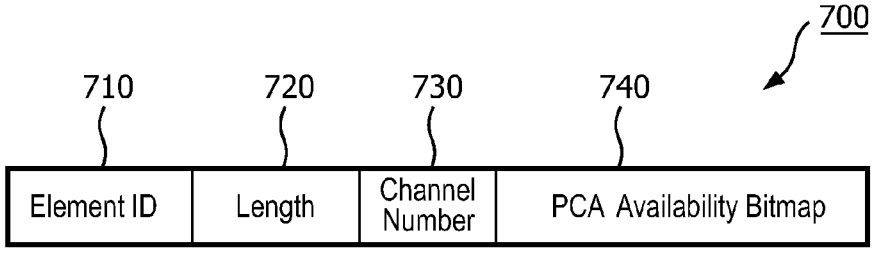


FIG. 7

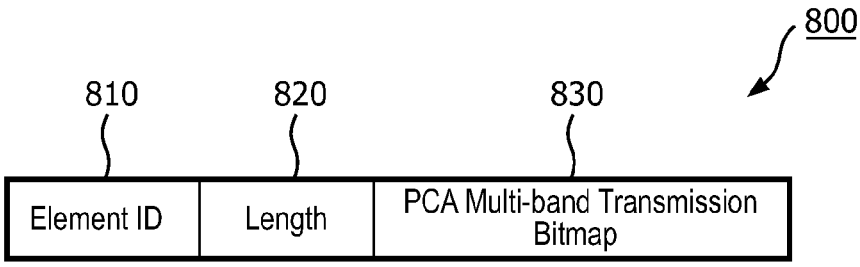

800
810
820
830
Element ID
Length
PCA Multi-band Transmission Bitmap

FIG. 8

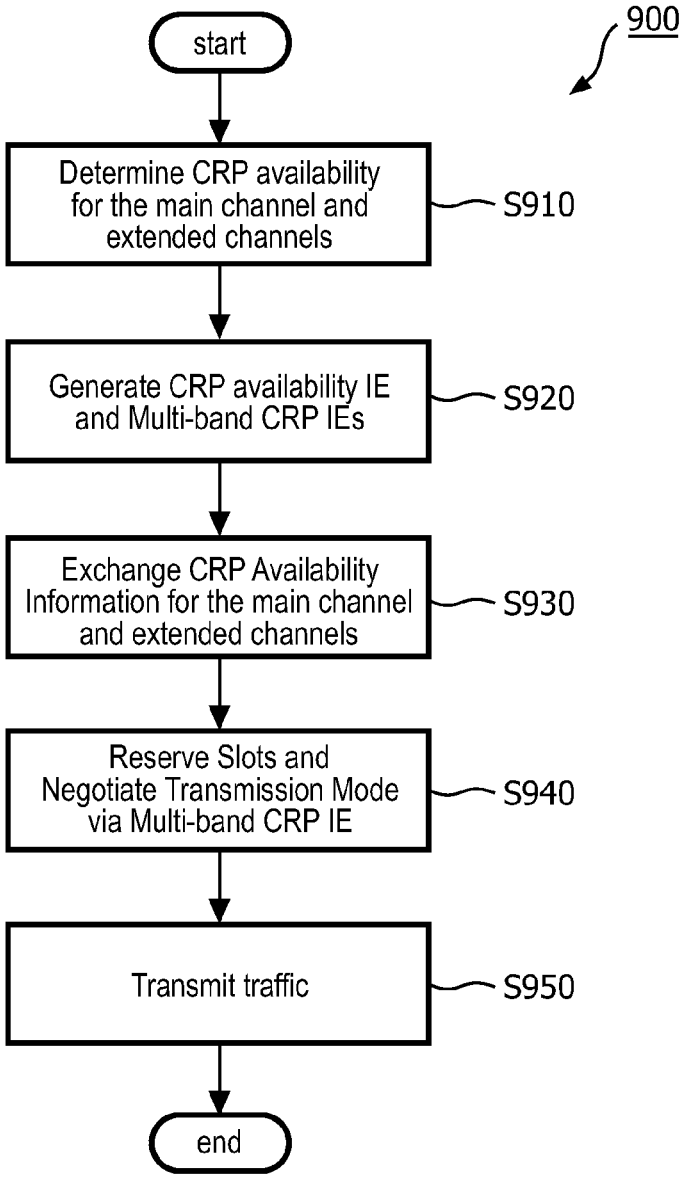

900
start
Determine CRP availability for the main channel and extended channels
S910
Generate CRP availability IE and Multi-band CRP IEs
S920
Exchange CRP Availability Information for the main channel and extended channels
S930
Reserve Slots and Negotiate Transmission Mode via Multi-band CRP IE
S940
Transmit traffic
S950
end

FIG. 9

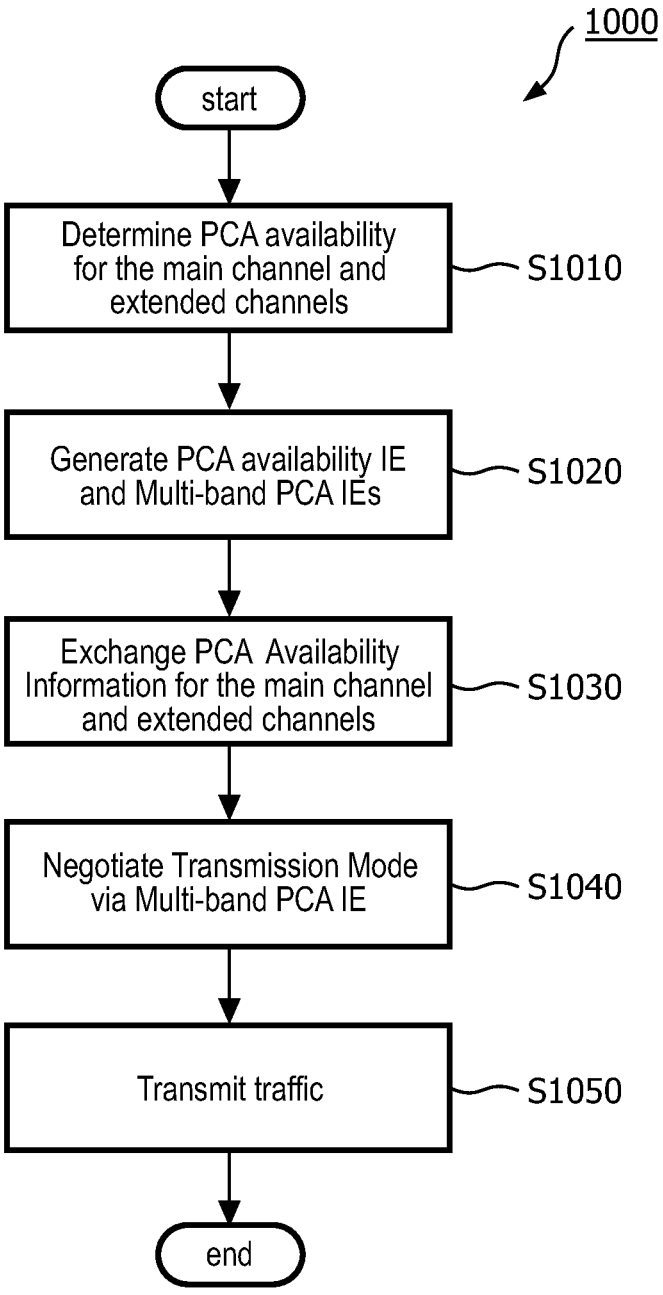

1000
start
Determine PCA availability for the main channel and extended channels
S1010
Generate PCA availability IE and Multi-band PCA IEs
S1020
Exchange PCA Availability Information for the main channel and extended channels
S1030
Negotiate Transmission Mode via Multi-band PCA IE
S1040
Transmit traffic
S1050
end

FIG. 10

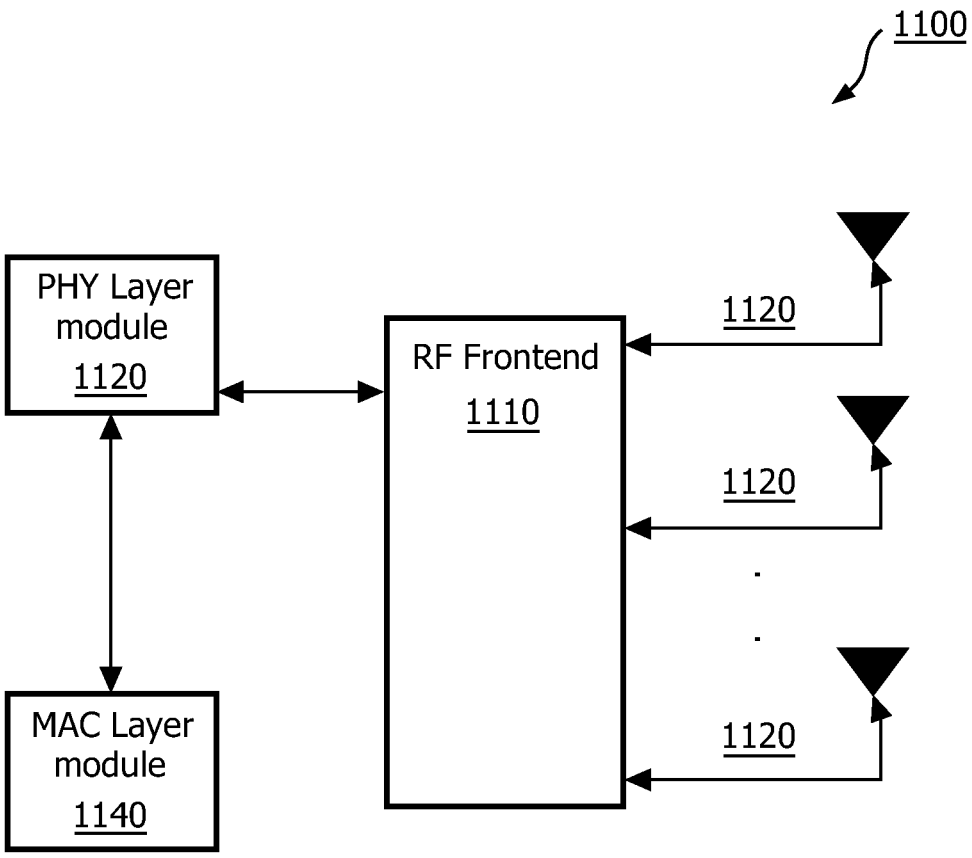

1100
PHY Layer module 1120
RF Frontend 1110
MAC Layer module 1140
1120
1120
1120

FIG. 11

METHOD AND SYSTEM FOR ENABLING MULTIPLE TRANSMISSION IN WIRELESS SYSTEMS

The invention generally relates to transmission in wireless systems, and more particularly, to techniques for enabling multiband transmission in such systems.

A wireless device equipped with a cognitive radio or spectrum-agile radio may communicate with another device through more than one channel, if such channels are available. For example, FIG. **1** illustrates a group of wireless devices in a multiband communication system **100**. A device **110**-A is a legacy device, a device **110**-B is a dual-band capable device, and devices **110**-C and **110**-D are tri-band devices. The device **110**-A can communicate with any device in the system **100** only through a main channel. The device **110**-B can receive and transmit signals through two channels, while the devices **110**-C and **110**-D can transmit and receive signals through three channels. The main channel is a channel on which all devices **110**-A through **110**-D in the system **100** can communicate.

Currently-defined medium access control (MAC) protocols allow access through a single channel. An example of such a protocol is a slot-based distributed MAC protocol the operation of which is illustrated in FIG. **2**. Each recurring superframe **210** consists of a predefined number of medium access slots (MASs): slots **220**. Each slot **220** can be reserved for a contention-free reservation access (CRA) via a channel reservation protocol (CRP) or open for prioritized contention access (PCA) if not reserved.

A wireless device with capabilities to access a slot **220** across multiple adjacent channels may bond these channels together for multiband transmission. As shown in FIG. **2**, the group of slots **220**-DB are reserved for dual-band communication between devices **110**-B and **110**-C on a main and first extended channels. The group of slots **220**-TB are reserved for tri-band communication between devices **110**-C and **110**-D on the main, first and second extended channels.

Devices synchronize with each other and negotiate the ownership and use policy of a set of slots **220** via beacons. Beacons are preferably transmitted on the main channel during a beacon period (BP). According to the agreed ownership and the use policy on the slots **220**, data communication can be carried on the main channel and extended channels.

In order to reserve a slot **220**, a device should know the availability of all slots **220** in a superframe **210**. In the related art, a mechanism is defined for single-channel based wireless systems. The mechanism generally includes information elements (IEs) for specifying the availability of slots **220**. Typically, a CRP Availability IE **310** and PCA Availability IE **320**, illustrated in FIGS. **3**A and **3**B respectively, are utilized for this purpose. With this aim, the IE **310** and **320** respectively include Availability Bitmap fields **301** and **302**, each of which consists of bits as the number of slots **220** in a superframe **210**, where each bit indicates if a respective slot is available. Specifically, each of the already defined Availability Bitmap fields **301** and **302** include 256 bits, one bit for each slot **220** in the superframe **210**. The least-significant bit usually corresponds to the first slot in the superframe and successive bits correspond to successive slots. Each bit is set to '1' if the device is available in the corresponding slot, or is set to '0' otherwise. In addition, if the length of the Availability Bitmap field (either **301** or **302**) is smaller than 32 octets, the bits in octets not included at the end of the bitmap are treated as '0'. If a set of slots **220** is available for reservation, a CRP IE is used to negotiate a reservation or part of a reservation for certain slots **220** and to announce the reserved slots. An exemplary format of a CRP IE **400** is depicted in FIG. **4**. Among other fields, the CRP IE **400** includes a CRP control field **410** and a number of M (where M is an integer number greater than 1) CRP allocation fields **420**. The CRP control field **410** defines the status and policy set for a reservation. A CRP allocation field **420** includes a MAS Bitmap field **421** and Zone Bitmap field **422** that identifies the zones that contain reserved slots. If a bit in the field **422** is set to a logic value '1', the corresponding zone contains reserved slots **220** and a zero bit corresponds to zone zero. The MAS Bitmap **421** specifies which slots **220** in the zones identified by the Zone Bitmap field **422** are parts of the reservation. If a bit in the MAS Bitmap **421** is set to a logic value '1', the corresponding slot **220** within each zone identified by the Zone Bitmap **422** is included in the reservation.

As can be understood from the above discussion, the CRP IE **400** can be used only in a single-channel system. The slot-based distributed MAC protocol does not define any provisioning and data structure format that can be utilized in a system where the negotiation of the ownership and the use policy of slots are performed in the main channel while data communication can be scheduled on multiple channels. Therefore, current MAC protocols do not enable multiband transmission in wireless systems.

Certain embodiments of the invention include a method for medium access reservation in a multiband wireless network. The method comprises determining available slots for reservation in a superframe for reservation across multiple channels; generating channel reservation protocol (CRP) availability information element (IE) to indicate the available slots on a main channel and one or more Extended-Channel CRP availability IEs to indicate the available slots on one more respective extended channels; exchanging the CRP availability IE and the Extended-Channel CRP availability IEs between a receiving device and a transmitting device; and generating a Multiband CRP IE to reserve slots that are available both on the receiving device and the transmitting device.

Certain embodiments of the invention also include a multiband wireless device. The device comprises at least one antenna for transmitting and receiving signals on multiple different channels; a radio frequency (RF) frontend connected to the multiple antennas; a physical layer module for identifying on which channels signals are received and on which channels signals are transmitted; and a medium access control (MAC) layer module for controlling an access to the medium across multiple channels by reserving slots in a superframe using a contention-free reservation access (CRA).

The subject matter that is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features and advantages of the invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings.

FIG. **1** is a diagram of an exemplary multiband communication system;

FIG. **2** is an illustration of operation of a slot-based distributed MAC protocol;

FIG. **3**A is an illustration of a CRP Availability IE format;

FIG. **3**B is an illustration of a PCA Availability IE format;

FIG. **4** is an illustration of a CRP IE format;

FIG. **5** is an illustration of an Extended-Channel CRP Availability IE format in accordance with an embodiment of the invention;

FIG. **6** is an illustration of a Multiband CRP IE format in accordance with an embodiment of the invention;

FIG. **7** is an illustration of an Extended-Channel PCA Availability IE format in accordance with an embodiment of the invention;

FIG. **8** is an illustration of a Multiband PCA IE format in accordance with an embodiment of the invention;

FIG. **9** is a flowchart describing a method for establishing CRA in a multiband wireless network in accordance with an embodiment of the invention;

FIG. **10** is a flowchart describing a method for establishing PCA in a multiband wireless network in accordance with an embodiment of the invention; and

FIG. **11** is a block diagram of a multiband wireless device in accordance with an embodiment of the invention.

It is important to note that the embodiments disclosed are only examples of the many advantageous uses of the innovative teachings herein. In general, statements made in the specification of the present application do not necessarily limit any of the various claimed inventions. Moreover, some statements may apply to some inventive features but not to others. In general, unless otherwise indicated, singular elements may be in plural and vice versa with no loss of generality. In the drawings, like numerals refer to like parts through several views.

Various embodiments of the invention include a method and data structures that enable multiband transmission in wireless networks. According to certain aspects of the invention, medium access time slots can be reserved on one more channels for a contention-free reservation access or a prioritized contention access. Certain embodiments are applicable for wireless systems that support multi-band communication. That is, at least two or more devices in the wireless system should be capable to receive and transmit signals in more than one band. Examples of such systems include, but are not limited to, wireless personal area networks (WPANs) compliant with cognitive radio standards, e.g., Ecma 392, ultra-wide band standards, e.g., Ecma 368, and High Rate 60 GHz standards, e.g., Ecma 387. Certain embodiments can also be implemented in Wi-Fi based wireless systems that operate in a distributed MAC mode.

FIG. **5** depicts a format of an Extended-Channel CRP Availability IE **500**. The IE **500** includes the following fields: an element identifier (ID) **510**, a length **520** for designating the length of the IE **500**, a channel number **530**, and a CRP availability Bitmap **540**. The channel number field **530** designates an absolute number (or an offset number) of an extended channel on which slots reservation is required. An extended channel is any other available channel in the wireless system, other than the main channel.

The Bitmap field **540** consists of bits as the number of slots (e.g., slots **220**) in a superframe (e.g., superframe **210**), where each bit indicates whether a respective slot is available on the extended channel. The Extended-Channel CRP Availability IE **500** is generated per each available extended-channel and is transmitted on the main channel in a beacon or part of a command frame. To allow backward compatibility and to announce CRP availability for the main channel, a CRP Availability IE **310** (shown in FIG. **3**A) is also transmitted on the main channel in a beacon or part of a command frame.

It should be appreciated that the use of the main channel to exchange the legacy CRP availability IE **310** and one or more Extended-channel CRP availability IEs **500** allow two heterogeneous devices to interoperate with each other. For example, a legacy single-band device (e.g., device **110**-A) can interoperate with a tri-band device (e.g., device **110**-D). Similarly, a dual-band device (e.g., a device **110**-B) can interoperate with a tri-band device. It should be noted that a multi-band device may transmit one or more IEs **500**, one per extended channel, in its beacon or command frame.

The CRP availability IEs **310** and **500** provide guidance for further channel reservation. That is, a slot can be reserved for transmission on each and every channel where the slot is available. For example, if a slot is available only on the main channel, the slot can be reserved only for the single-band transmission. If a slot is available on both the main and first extended channels, then it can be reserved for dual-band transmission. In a similar fashion, if a slot is available on the main, first extended, and second extended channels, it can be reserved for tri-band transmission. In accordance with an embodiment of the invention, a reservation or a part of a reservation for certain slots are negotiated between devices using a Multi-band CRP IE **600**. The IE **600** is also utilized to announce the ownership and the transmission mode of the reserved slots.

The IE **600** is based on the legacy CRP IE **400** and shown in FIG. **6**. The CPR control field **610** is modified to include a bonding mode sub-field **611** to negotiate and announce the transmission mode. In an exemplary embodiment, the bonding mode sub-field **611** includes two bits encoded as illustrated in Table 1. If the bonding mode bits are set to 00, it indicates a single-band transmission on the main channel. If bonding mode bits are set to 01, it indicates a dual-band transmission on the main channel and the first extended channel. Similarly, if the bonding mode bits are set to 10, it indicates tri-band transmission on the main channel, the first extended channel, and the second extended channel.

TABLE 1

Bonding Mode Bits Values	Transmission type
00	Single-band
01	Dual-band
10	Tri-band
11	reserved

FIG. **7** depicts a format of an Extended-Channel PCA Availability IE **700**. The IE **700** includes the following fields: an element identifier (ID) **710**, a length **720** for designating the length of the IE **700**, a channel number **730**, and a PCA availability Bitmap **740**. The channel number field **730** designates an absolute number (or an offset number) of an extended channel for which the IE **700** is generated. The Bitmap field **740** consists of bits as the number of slots (e.g., slots **220**) in a superframe (e.g., superframe **210**), where each bit indicates if a respective slot is available to receive PCA traffic and transmit the required response in the corresponding slot on the extended channel.

The Extended-Channel PCA Availability IE **700** is generated per each available extended-channel and is transmitted on the main channel in a beacon or part of a command frame. To allow backward compatibility and to announce PCA availability for the main channel, a PCA Availability IE **320** (shown in FIG. **3**A) is also transmitted on the main channel in a beacon or part of a command frame. Similar to the CRP availability IEs, the combined use of legacy PCA availability IE **320** and one or more Extended-Channel PCA availability IEs **700** allow two heterogeneous devices to interoperate with each other.

FIG. **8** illustrates a Multiband PCA IE **800** utilized to facilitate multi-band transmission using PCA in accordance with an embodiment. The PCA IE **800** includes the following fields: an element ID **810**, a length **820** for designating

the total length of IE **800**, and a PCA Multi-band Transmission Bitmap field **830**. The field **830** includes r*s bits, where 's' is the number of slots in each superframe and 'r' is an integer number greater than one. In accordance with one embodiment, the value of the parameter 'r' may be equal to 2 and the field **830** is 512 bits long. According to this embodiment, the least-significant two bits of the field **830** correspond to the first slot in the superframe and successive bits correspond to successive slot. Each two bits in the field **830** are encoded to represent the transmission mode allowed on the respective time slot, e.g., main channel, dual-band, and tri-band. Table 2 shows exemplary encoding values for each two bits corresponding to a slot in a superframe. If the value of 's' is less than the total number of slots (e.g., 256) in a superframe, the bits not included at the end of the field **830** are treated as '0'.

TABLE 2

Bits Values	PCA Transmission Type
00	Not allowed
01	Single-band
10	Dual-band
11	Tri-band

FIG. **9** shows a non-limiting and exemplary flowchart **900** describing a method for establishing contention-free reservation access (CRA) in a multiband wireless network. The method is executed by a device having multiband transmission capabilities, where data is transmitted in multiple channels to a receiving device with multiband capabilities.

At S**910**, the slots available in a superframe for reservation across multiple channels are determined. At S**920**, a CRP availability IE (e.g., IE **310**) and one or more Extended-Channel CRP availability IEs (e.g., IE **500**) are generated to indicate the available slots on the main channel and each extended channel that the receiving device supports. Such IEs may also be generated by the transmitting device. At S**930**, the generated IEs are exchanged between the transmitting device and receiving device. At S**940**, the transmitting device generates a Multiband CRP IE (e.g., IE **600**) to reserve slots that are available both on the receiving and transmitting devices and to announce the transmission mode. For example, if the receiving and transmitting devices are dual-band devices, then the bonding mode field will be set to a value of '01' indicating a dual-band transmission. The MAS bitmap in IE **600** will be set to indicate a group of slots reserved on the main and first extended channels, for example, group of slots **220**-DB, shown in FIG. **2**. It should be noted that IEs **310**, **500**, and **600** are transmitted on the main channel. At S**950**, data is transmitted on the reserved slots on multiple channels according to an agreed transmission mode and policy.

Unreserved slots can be utilized for transmission of PCA traffic. A non-limiting and exemplary flowchart **1000** of a method for establishing prioritized contention access (PCA) is depicted in FIG. **10**. The method is executed by a device having multiband transmission capabilities, where data is transmitted on multiple channels to a receiving device with multiband capabilities.

At S**1010**, the slots available in a superframe for PCA across multiple channels are determined. At S**1020**, a PCA availability IE (e.g., IE **320**) and one or more Extended-Channel PCA availability IEs (e.g., IE **700**) are generated to indicate the available slots on the main channel and each extended channel that the receiving device supports. Such IEs may also be generated by the transmitting device. At S**1030**, the generated IEs are exchanged between the transmitting device and receiving device. At S**1040**, the transmitting device generates a Multiband PCA IE (e.g., IE **800**) to negotiate the transmission mode with the receiving device. For example, if the receiving and transmitting devices are dual-band devices, then each two-bits in the PCA Multiband Transmission Bitmap **830** corresponding to an available slot is set to a value of '10' (see Table 2) indicating a dual-band transmission. It should be noted that IEs **320**, **700** and **800** are transmitted on the main channel. At S**1050**, data is transmitted on available and unreserved slots according to an agreed transmission mode and policy.

FIG. **11** shows an exemplary and non-limiting block diagram of a multiband wireless device **1100**. The wireless device **1100** includes a radio frequency (RF) frontend **1110** connected to multiple antennas **1120** for transmitting and receiving signals on different channels, each channel operating in a different frequency band. The wireless device **1100** also includes a physical (PHY) layer module **1130** and a MAC layer module **1140**. The PHY layer module **1130**, in addition to performing typical PHY layer operations for interfacing with a wireless medium, identifies on which channels signals are received and on which channels signals are transmitted. The MAC layer module **1140** generates the IEs described in detail above and controls the access to the medium by establishing contention-free reservation access (CRA) and/or prioritized contention access (PCA) as described in detail above.

The principles of various embodiments of the invention can be implemented as hardware, firmware, software or any combination thereof. Moreover, the software is preferably implemented as an application program tangibly embodied on a program storage unit, a non-transitory computer readable medium, or a non-transitory machine-readable storage medium that can be in a form of a digital circuit, an analogy circuit, a magnetic medium, or combination thereof. The application program may be uploaded to, and executed by, a machine comprising any suitable architecture. Preferably, the machine is implemented on a computer platform having hardware such as one or more central processing units ("CPUs"), a memory, and input/output interfaces. The computer platform may also include an operating system and microinstruction code. The various processes and functions described herein may be either part of the microinstruction code or part of the application program, or any combination thereof, which may be executed by a CPU, whether or not such computer or processor is explicitly shown. In addition, various other peripheral units may be connected to the computer platform such as an additional data storage unit and a printing unit.

The foregoing detailed description has set forth a few of the many forms that the invention can take. It is intended that the foregoing detailed description be understood as an illustration of selected forms that the invention can take and not as a limitation to the definition of the invention. It is only the claims, including all equivalents that are intended to define the scope of this invention.

The invention claimed is:

1. A method for medium access reservation in a multiband wireless network, comprising:

determining available slots for reservation in a superframe for reservation across multiple channels;

generating channel reservation protocol, CRP, availability information element, IE, to indicate the available slots on a main channel;

generating one or more Extended-Channel CRP availability IEs to indicate the available slots on one or more respective extended channels;

exchanging, over a main channel, the CRP availability IE and the Extended-Channel CRP availability IEs between a receiving device and a transmitting device, wherein the main channel is a communication channel on which all devices can communicate in a single-channel configuration and a multiband configuration; and

generating a Multiband CRP IE to reserve slots that are available on the receiving device and the transmitting device, wherein the Multiband CRP IE is configured for negotiation, between the transmitting device and the receiving device, for the reserved slots based on the generated CRP availability IE and Extended-Channel CRP availability IEs.

2. The method of claim **1**, wherein the CRP availability IE and the Extended-Channel CRP availability IEs are exchanged on the main channel using any one of a beacon and a command frame.

3. The method of claim **1**, wherein an Extended-Channel CRP availability IE includes an element ID field, a length field for designating the length of the Extended-Channel CRP availability IE, a channel number field for designating a channel of an extended channel on which a reservation is targeted, and a CRP availability Bitmap field for designating the available slots.

4. The method of claim **1**, wherein the Multiband CRP IE is further utilized to announce ownership of the reserved slots.

5. The method of claim **4**, wherein the Multiband CRP IE is further utilized to announce a transmission mode of the reserved slots.

6. The method of claim **5**, wherein the Multiband CRP IE comprises at least a bonding mode sub-field being encoded to indicate the transmission mode.

7. The method of claim **5**, wherein the transmission mode includes at least one of: a single-band transmission on the main channel, a dual-band transmission on the main channel and a first extended channel, and a tri-band transmission on the main channel, the first extended channel, and a second extended channel.

8. The method of claim **1**, further comprising establishing prioritized contention access, PCA, for unreserved slots in the superframe.

9. The method of claim **8**, further comprising:

determining available slots for PCA across multiple channels;

generating PCA availability IE to indicate the available slots on a main channel;

generating one or more Extended-Channel PCA availability IEs to indicate the available slots on one or more respective extended channels;

exchanging, over the main channel, the PCA availability IE and the Extended-Channel PCA availability IEs between the receiving device and the transmitting device; and

generating a Multiband PCA IE to negotiate a transmission mode between the transmitting device and the receiving device based on the generated PCA availability IE and Extended-Channel PCA availability IEs.

10. The method of claim **9**, wherein an Extended-Channel PCA availability IE includes an element ID field, a length field for designating the length of the Extended-Channel PCA availability IE, a channel number field for designating a channel number of an extended channel for which Extended-Channel PCA availability IE is generated, and a PCA availability Bitmap field for designating unreserved slots that can be utilized for data transmission via PCA.

11. The method of claim **9**, wherein the Multiband PCA IE includes an element ID field, a length field for designating a total length of the Multiband PCA IE, and a PCA Multiband Transmission Bitmap field including r*s bits, wherein 's' is a number of slots in the superframe and 'r' is an integer number greater than one, wherein each 'r' bits are encoded to designate the transmission mode of a respective slot.

12. The method of claim **9**, wherein the PCA availability IE and the Extended-Channel PCA availability IEs are transmitted on the main channel using either a beacon or a command frame.

13. A non-transitory computer readable medium having stored thereon instructions for causing one or more processing units to execute the method according to claim **1**.

14. A multiband wireless device comprising:

at least one antenna for transmitting and receiving signals on multiple different channels;

a radio frequency, RF, frontend connected to the at least one antenna;

a physical layer module for identifying on which channels signals are received and on which channels signals are transmitted;

a medium access control, MAC, layer module for controlling an access to the medium across multiple channels by reserving slots in a superframe using a contention-free reservation access, CRA; and

a processing circuit configured to:

determine available slots for reservation in a superframe for reservation across multiple channels;

generate channel reservation protocol, CRP, availability information element, IE, to indicate the available slots on a main channel;

generate one or more Extended-Channel CRP availability IEs to indicate the available slots on one or more respective extended channels;

exchange, over a main channel, the CRP availability IE and the Extended-Channel CRP availability IEs between a receiving device and a transmitting device, wherein the main channel is a communication channel on which all devices can communicate in a single-channel configuration and a multiband configuration; and

generate a Multiband CRP IE to reserve slots that are available on the receiving device and the transmitting device, wherein the Multiband CRP IE is configured for negotiation, between the transmitting device and the receiving device, for the reserved slots based on the generated CRP availability IE and Extended-Channel CRP availability IEs.

15. The multiband wireless device of claim **14**, wherein the MAC layer module further establishes a prioritized contention access (PCA) for unreserved slots in the superframe.

16. The multiband wireless device of claim **14**, wherein the Multiband CRP IE is further utilized to announce ownership of the reserved slots.

17. The multiband wireless device of claim **16**, wherein the Multiband CRP IE is further utilized to announce a transmission mode of the reserved slots.

18. The multiband wireless device of claim **17**, wherein the Multiband CRP IE comprises at least a bonding mode sub-field being encoded to indicate the transmission mode.

19. The multiband wireless device of claim **14**, wherein an Extended-Channel CRP availability IE includes an element

ID field, a length field for designating the length of the Extended-Channel CRP availability IE, a channel number field for designating a channel of an extended channel on which a reservation is targeted, and a CRP availability Bitmap field for designating the available slots.

* * * * *